BUILD-A-CONTAINER WORKSHOP

Container Anatomy

Contents

10 MINUTE READ

If you are new to containers, this section will help your understanding in what actually makes up a container, introduce the Open Container Initiative (OCI) specifications and demystify some of what is actually happening under the covers.

1. What makes up a Container?

A Container can be defined as a process with its own file system. The process is governed by the OCI runtime specification (github.com/opencontainers/runtime-spec) whilst the file system and configuration is governed by the OCI container image format (github.com/opencontainers/image-spec).

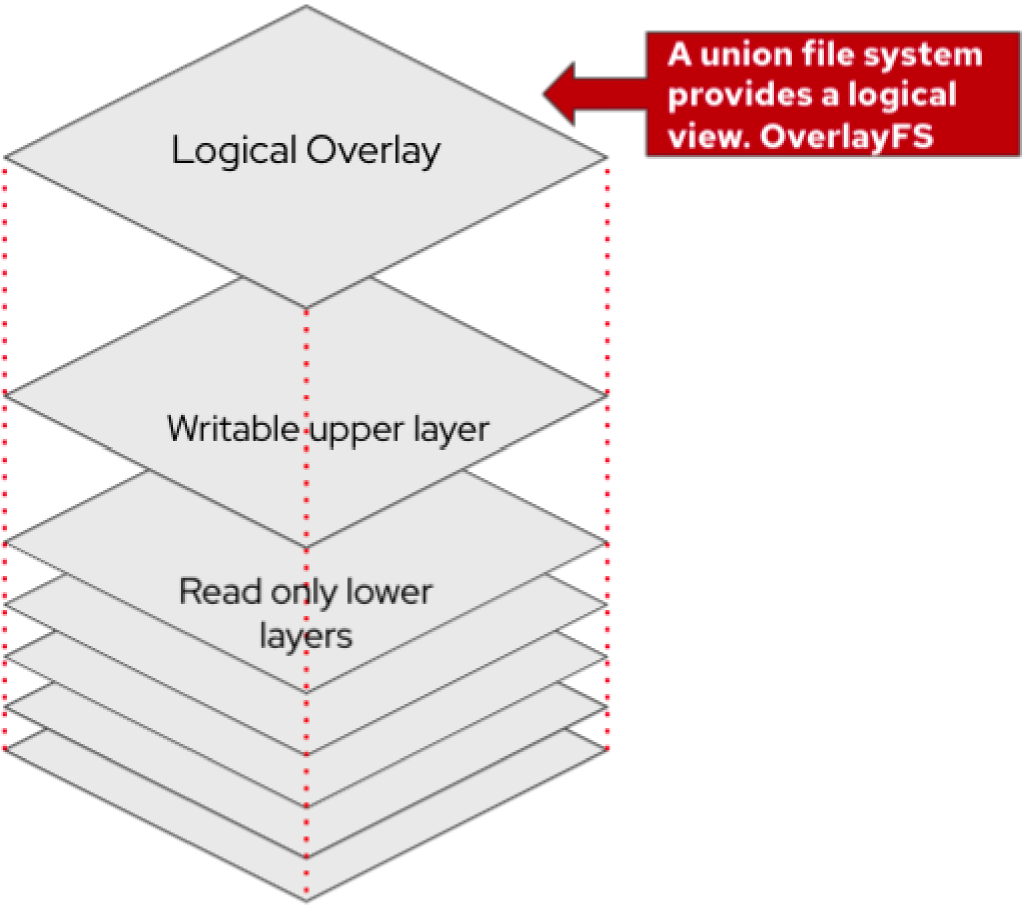
These specifications are open industry standards by the Open Container Initiative (OCI) which is an open governance structure for the express purpose of creating standards around container formats and runtimes.

2. Container Image Format

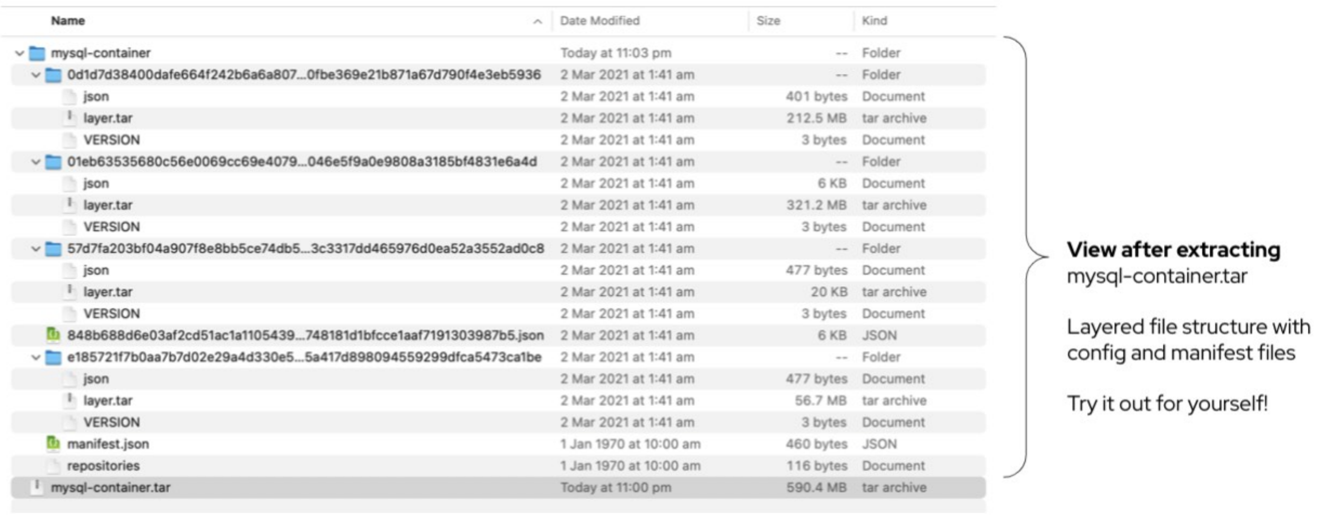
Container images are made up of layers, most of which are immutable with the exception of a write-able upper layer. A union file system provides a logical view when the container is running. (Over-layFS is a union mount filesystem implementation for Linux). The union file system works on top of the other file-systems. It gives a single coherent and unified view to files and directories of separate file-system. In other words, it mounts multiple directories to a single root. It is more of a mounting mechanism than a file system.

Today you are the container builder, so the important aspects to understand are:

1. Choose to have **fewer layers** as it takes less time to build the logical view union file system at runtime.
2. **Smaller container images are preferable** as they will take less time to download and use less disk space.
3. **Upper layers** may potentially **overwrite** bottom layers. So a file may not be present because it was deleted by an upper layer.
4. **Logically deleting** the file in the upper layer will **still add to overall image size**.



Within the container image, layers are formatted as archives (tar files) and are indexed in Image index and Manifest (json format) files. Furthermore config files provide the means of storing command line options, environment variables, and properties such as time created. The figure below shows the extract of a container image and how the internals of layering, indexing are organised.



Name	Date Modified	Size	Kind
mysql-container	Today at 11:03 pm	--	Folder
0d1d7d38400dafe664f242b6a6a807...0fbe369e21b871a67d790f4e3eb5936	2 Mar 2021 at 1:41 am	--	Folder
json	2 Mar 2021 at 1:41 am	401 bytes	Document
layer.tar	2 Mar 2021 at 1:41 am	212.5 MB	tar archive
VERSION	2 Mar 2021 at 1:41 am	3 bytes	Document
01eb63535680c56e0069cc69e4079...046e5f9a0e9808a3185bf4831e6a4d	2 Mar 2021 at 1:41 am	--	Folder
json	2 Mar 2021 at 1:41 am	6 KB	Document
layer.tar	2 Mar 2021 at 1:41 am	321.2 MB	tar archive
VERSION	2 Mar 2021 at 1:41 am	3 bytes	Document
57d7fa203bf04a907f8e8bb5ce74db5...3c3317dd465976d0ea52a3552ad0c8	2 Mar 2021 at 1:41 am	--	Folder
json	2 Mar 2021 at 1:41 am	477 bytes	Document
layer.tar	2 Mar 2021 at 1:41 am	20 KB	tar archive
VERSION	2 Mar 2021 at 1:41 am	3 bytes	Document
848b688d6e03af2cd51ac1a1105439...748181d1bfcce1aaf7191303987b5.json	2 Mar 2021 at 1:41 am	6 KB	JSON
e185721f7b0aa7b7d02e29a4d330e5...5a417d898094559299dfca5473ca1be	2 Mar 2021 at 1:41 am	--	Folder
json	2 Mar 2021 at 1:41 am	477 bytes	Document
layer.tar	2 Mar 2021 at 1:41 am	56.7 MB	tar archive
VERSION	2 Mar 2021 at 1:41 am	3 bytes	Document
manifest.json	1 Jan 1970 at 10:00 am	460 bytes	JSON
repositories	1 Jan 1970 at 10:00 am	116 bytes	Document
mysql-container.tar	Today at 11:00 pm	590.4 MB	tar archive

View after extracting mysql-container.tar

Layered file structure with config and manifest files

Try it out for yourself!

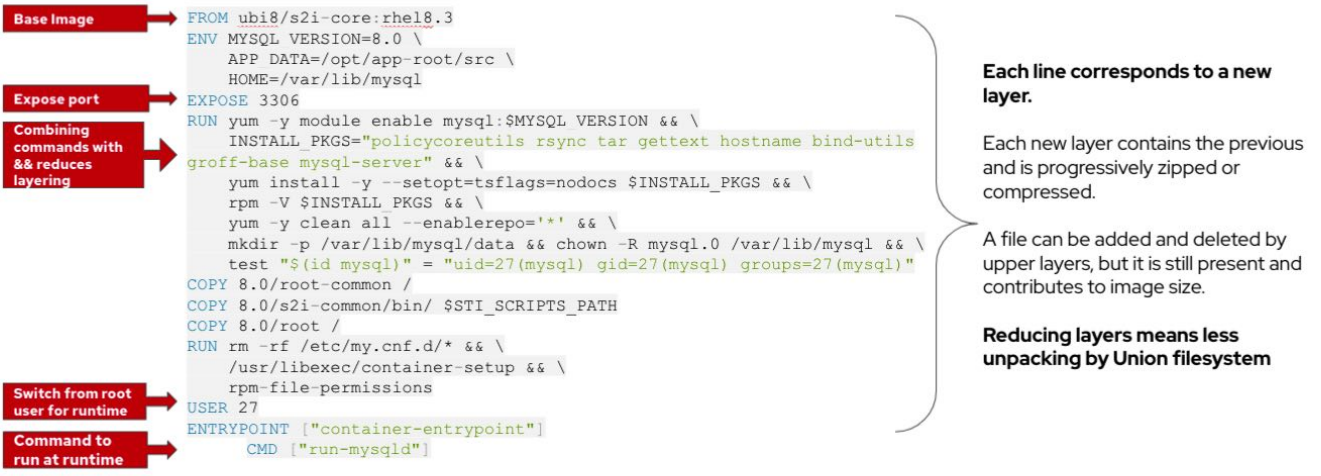
NOTE

The above container image was exported to a tar file with the podman save command.

3. Containerfile

A Containerfile is a text based file which provides instructions to assemble an image. **Each row in a Containerfile corresponds to a new layer**. The available commands that are usable inside a Containerfile and a Dockerfile are equivalent.

The Containerfile below is a mysql image from the Red Hat Container Catalog.



```
FROM ubi8/s2i-core:rhel8.3
ENV MYSQL_VERSION=8.0 \
    APP_DATA=/opt/app-root/src \
    HOME=/var/lib/mysql
EXPOSE 3306
RUN yum -y module enable mysql:$MYSQL_VERSION && \
    INSTALL_PKGS="policycoreutils rsync tar gettext hostname bind-utils
groff-base mysql-server" && \
    yum install -y --setopt=tsflags=nodocs $INSTALL_PKGS && \
    rpm -V $INSTALL_PKGS && \
    yum -y clean all --enablerepo='*' && \
    mkdir -p /var/lib/mysql/data && chown -R mysql.0 /var/lib/mysql && \
    test "$(id mysql)" = "uid=27(mysql) gid=27(mysql) groups=27(mysql)"
COPY 8.0/root-common /
COPY 8.0/s2i-common/bin/ $STI_SCRIPTS_PATH
COPY 8.0/root /
RUN rm -rf /etc/my.cnf.d/* && \
    /usr/libexec/container-setup && \
    rpm-file-permissions
USER 27
ENTRYPOINT ["container-entrypoint"]
      CMD ["run-mysqld"]
```

Base Image
Expose port
Combining commands with && reduces layering
Switch from root user for runtime
Command to run at runtime

Each line corresponds to a new layer.

Each new layer contains the previous and is progressively zipped or compressed.

A file can be added and deleted by upper layers, but it is still present and contributes to image size.

Reducing layers means less unpacking by Union filesystem

As the image is built the commands are executed in order from top down until the image is built. The table below provides an overview of typical commands seen in a Containerfile.

FROM	To specify the parent image.
WORKDIR	To set the working directory for any commands that follow in the Dockerfile.
RUN	To install any applications and packages required for your container.

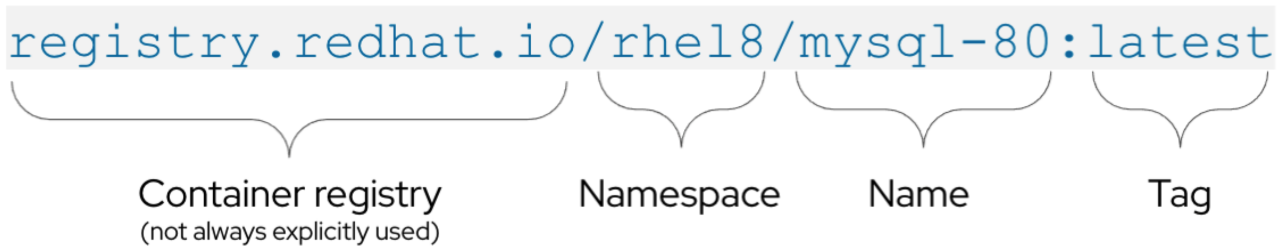
COPY	To copy over files or directories from a specific location.
ADD	As COPY, but also able to handle remote URLs and unpack compressed files.
ENTRYPOINT	Command that will always be executed when the container starts. If not specified, the default is /bin/sh -c
CMD	Arguments passed to the entrypoint. If ENTRYPOINT is not set (defaults to /bin/sh -c), the CMD will be the commands the container executes.
EXPOSE	To define which port through which to access your container application.
LABEL	To add metadata to the image.

You may also see Containerfiles with multistage builds where **multiple FROM commands** may be present. **Multistage builds** provide a means to help refine the runtime image as opposed to having an image which also contains all the necessary software to build. For instance you typically don't need maven to run a java based jar but do need it to build.

4. Container Identification

Once you build a container you need to give it a tag to be able to identify it. An image tag is a label applied to a container image in a repository that distinguishes a specific image from other images. Typically, the tag represents a version number of some sort.

Containers fully qualified image registry path is below:


registry.redhat.io/rhel8/mysql-80:latest
Container registry
(not always explicitly used)
Namespace
Name
Tag

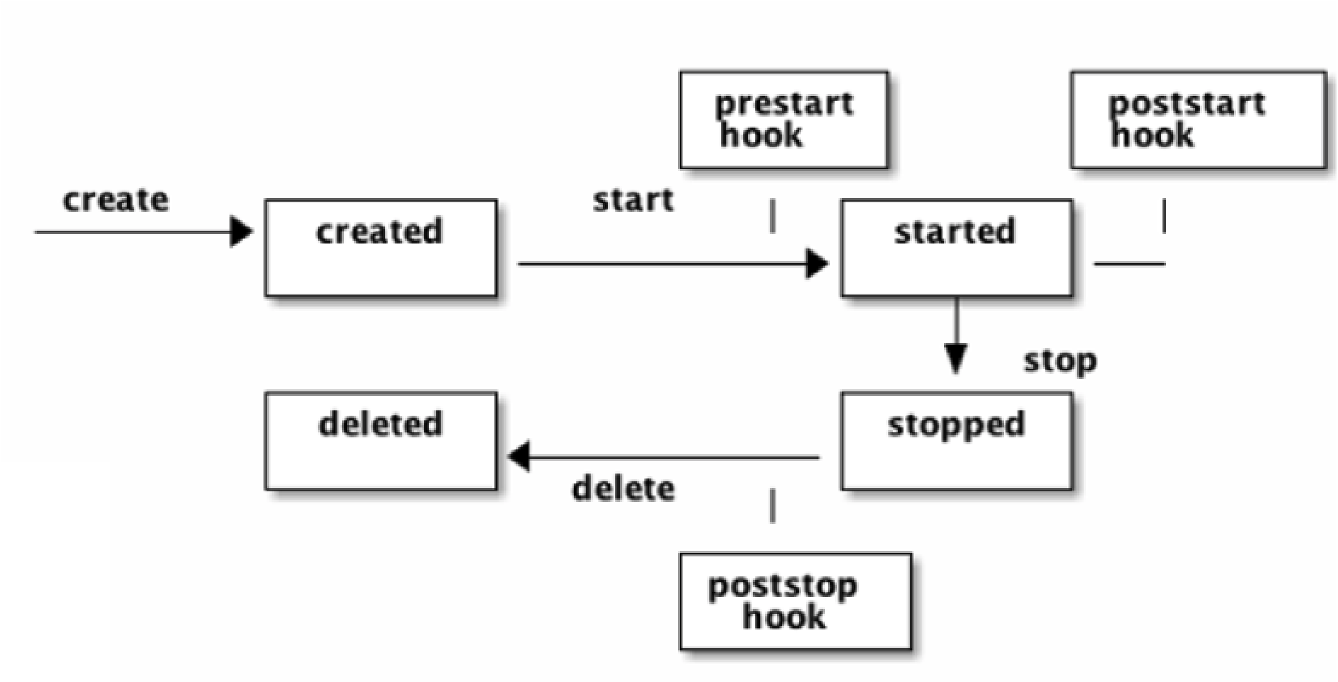
NOTE

If you only reference a container by its short name i.e. rhel8/mysql-80:latest , there will be an assumption made as to which register to try. For example in RHEL 8, the default registries that will be looked up are registry.access.redhat.com, registry.redhat.io, docker.io

Red Hat recommends that users always use fully qualified names when referring to container images in any context.

5. Container Runtime

Like the container image specification, there is a runtime specification which defines a lifecycle for a container. This defines hooks to be invoked prior to starting, creating or shutting down the container.



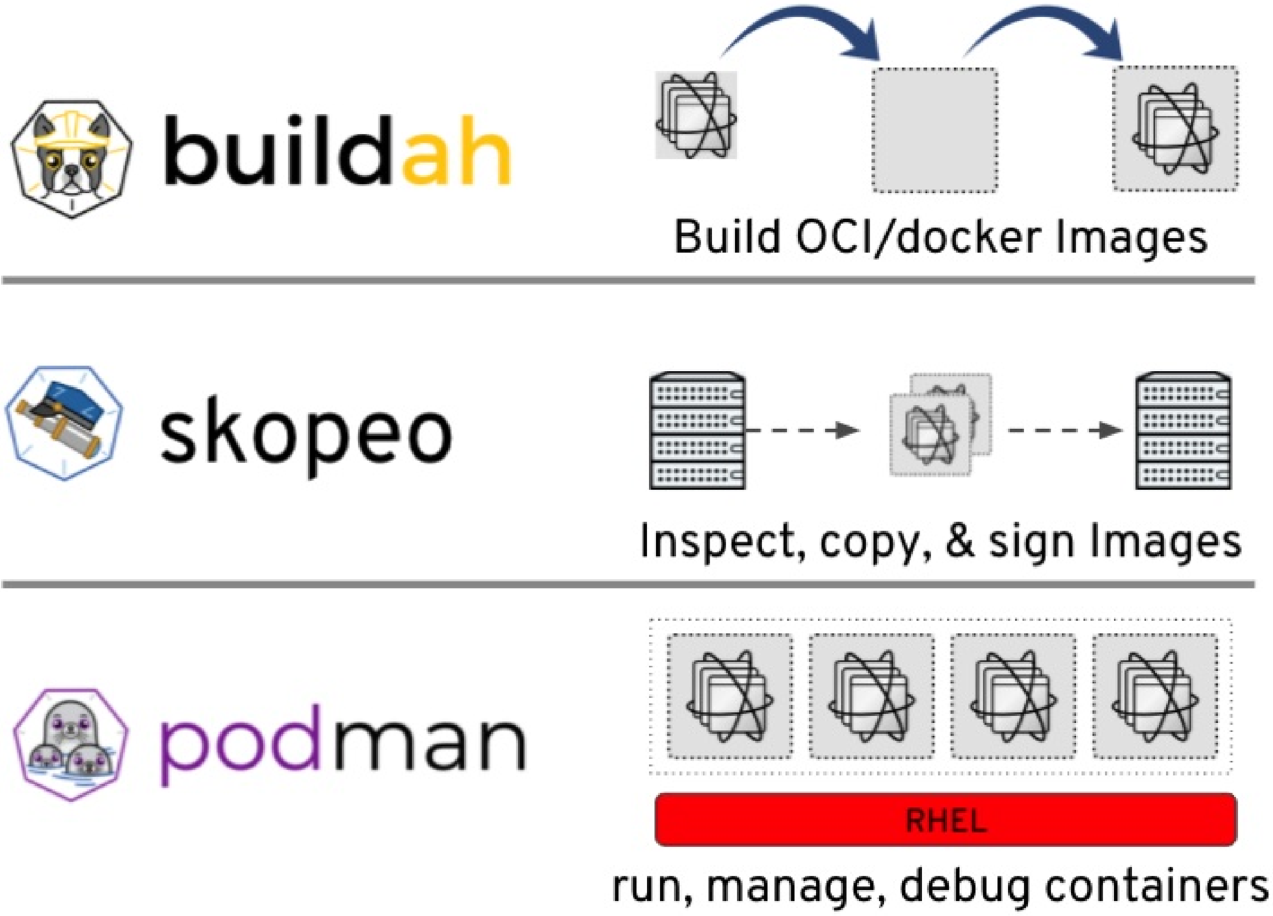
The state of a container includes properties like OCI Version, status, process id (pid) and container ID. The container id and must be unique across all containers on this host and can be found with the following command:

```
podman ps
CONTAINER ID IMAGE         COMMAND    CREATED    STATUS                PORTS
NAMES     IS INFRA
d65aecc325a4 ubi8/ubi      /bin/bash  3 secs ago Exited (0) 5 secs ago
peaceful_hopper false
74b1da000a11 rhel8/rsyslog rsyslog.sh 2 mins ago Up About a minute
musing_brown    false
```

6. Container Tools

The open source community has created new container tools to **eliminate the required use of root access and a daemon process** compared with how Docker is designed.

These new tools **buildah, skopeo and podman** each provide more focussed functionality. You can think of **podman as a developers replacement for Docker**, **skopeo** as a simpler way to inspect and copy images and **buildah** provides specialist ways of building images whether from a Containerfile or interactively.



But how would you use these tools? The commands are presented as examples to read and not run.

Podman

Podman command format will be very familiar to Docker users but doesnt require a daemon.

```
# Pull an image from the registry
podman pull registry.fedoraproject.org/f34/python3
# List images in local storage
podman images
# Run the container in the background and map ports
podman run -dt -p 8080:8080/tcp registry.fedoraproject.org/f29/httpd
```

Buildah

Buildah can act as a drop-in replacement for the Docker daemon’s docker build command (i.e., building images with a traditional Dockerfile) but is flexible enough to allow you to build images with whatever tools you prefer to use. (bud = build-using-dockerfile)

```
buildah bud -t hello .
```

is the same as

```
docker build -t hello .
```

Unlike Docker build, **Buildah doesn't commit changes to a layer automatically for every instruction** meaning it results in a single layer (great news for union file system performance). Furthermore it allows you to build images from scratch (i.e. no base container or no FROM image) so you can make containers as small as possible.

To use Buildah in an interactive mode:

1. Start with creating a working container with Buildah.

   The following saves the container name into the $container variable to use in subsequent commands. You can view working containers with the buildah containers command.

   ```
   # container=$(buildah from registry.access.redhat.com/ubi8/python-38)
   # echo $container
   python-38-working-container
   # buildah containers
   CONTAINER ID  BUILDER  IMAGE ID     IMAGE NAME
   CONTAINER NAME
   df1d24a08d19     *     a6d7938156c7 registry.access.redhat.com/ub... python-
   38-working-container
   ```

2. Interact with a bash shell as your are building it like below.

   ```
   # buildah run $container bash
   (app-root) bash-4.4$ mkdir scripts
   .....
   exit
   ```

3. Next add configuration, labels and environment variables.

   ```
   # buildah config --label maintainer="John Smith <john.smith@gmail.com>"
   $container
   # buildah config --env FLASK_APP=flaskr --env FLASK_ENV=development
   $container
   # buildah config --workingdir /opt/hello-2.10 $container
   # buildah config --entrypoint /usr/local/bin/hello $container
   # buildah copy $container hello-2.10.tar.gz /tmp/hello-2.10.tar.gz
   ```

4. Finally save the working container to an image hello:latest which will then be available to run

```
# buildah commit $container hello:latest
```

For more information see Getting started with Buildah

Skopeo

Inspect a container without needing the docker daemon.

```
skopeo inspect docker://docker.io/fedora
```

Copy containers from one registry to another.

```
skopeo copy --dest-creds prod_user:prod_pass
docker://internal.registry/myimage:latest
docker://production.registry/myimage:v1.0
```

In the single line above the skopeo copy command replaces the 4 commands below.

```
docker login ...
docker pull internal.registry/myimage:latest
docker tag internal.registry/myimage:latest production.registry/myimage:v1.0
docker push production.registry/myimage:v1.0
```

7. Container Registries

When working with container images, you need somewhere to save and access them as they are created and that’s where a container registry comes in. The registry essentially acts as a place to store container images and share them out via a process of uploading to (pushing) and downloading from (pulling).

There are two types of container registry: public and private.

Public registries are:

- great for individuals or small teams
- get up and running as quickly as possible. Basic in their abilities.
- easy to use

Private registries have:

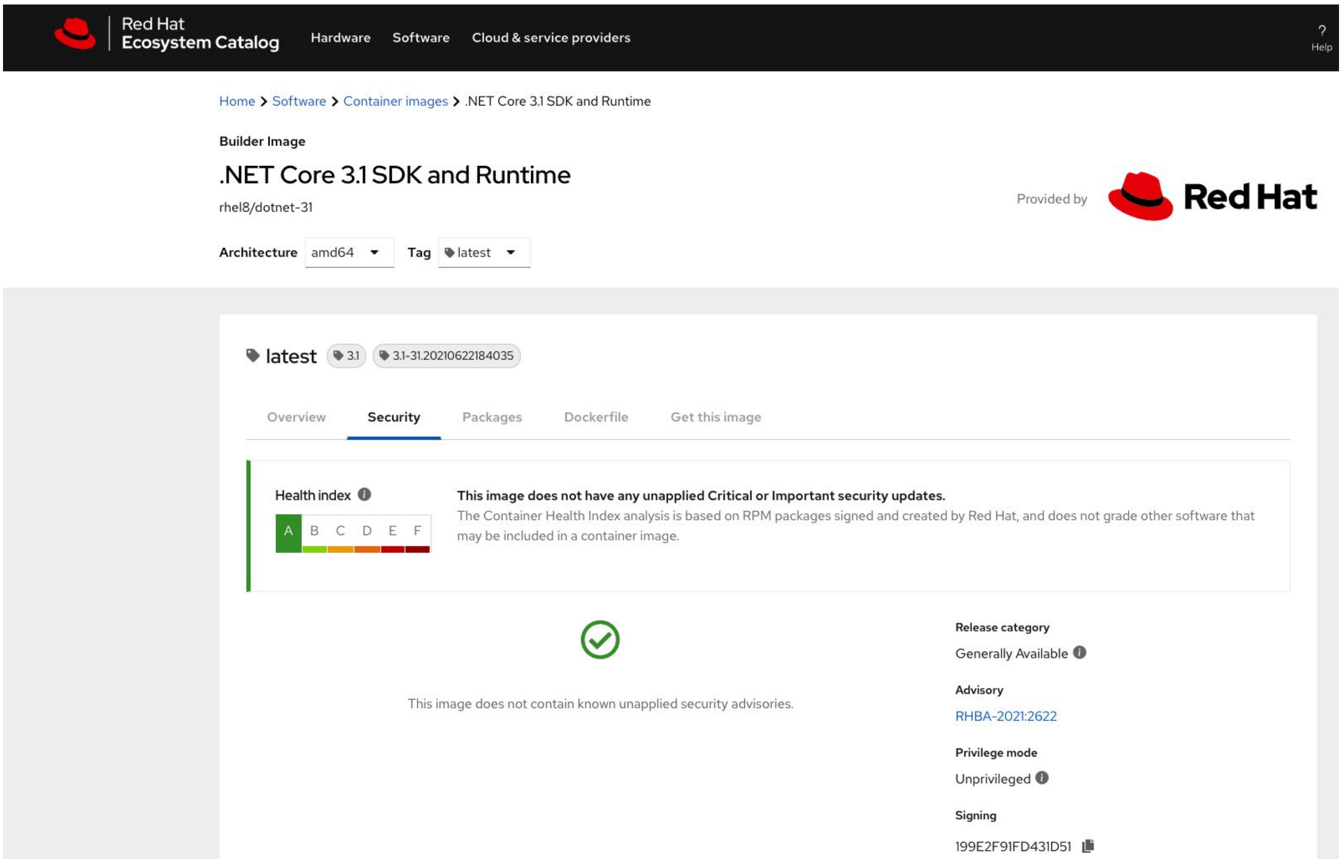
- Security and privacy
- Enterprise container image storage
- Host remotely or on-premises

Typically your enterprise will require a container registry and we recommend to look for features such as: multiple authentication systems; role-based access control management; vulnerability scanning capabilities; auditable logs and optimized for automation.

Red Hat's Enterprise Container Registry

Red Hat Quay is a private container image registry that enables you to build, distribute, and deploy containers with the storage you need to scale quickly. It analyzes your images for security vulnerabilities using Clair, identifying potential issues and addressing them before they become security risks.

You can try Quay through a free account with Quay.io which is a managed service OR browse the results of scanning through the Red Hat Container catalog like in the figure below.



Home > Software > Container images > .NET Core 3.1 SDK and Runtime

Builder Image

.NET Core 3.1 SDK and Runtime

rhel8/dotnet-31

Provided by Red Hat

Architecture amd64 Tag latest

latest 3.1 3.1-31.20210622184035

Health index

A B C D E F

This image does not have any unapplied Critical or Important security updates.

The Container Health Index analysis is based on RPM packages signed and created by Red Hat, and does not grade other software that may be included in a container image.

This image does not contain known unapplied security advisories.

Release category

Generally Available

Advisory

RHBA-2021:2622

Privilege mode

Unprivileged

Signing

199E2F91FD431D51

More information

But what else do you need to know about containers? Well you might want to understand

1. File system mounting
2. User permissions
3. Port mapping
4. Network
5. Resource limiting
6. Secrets, configuration, environment variables
7. Host system

Many of these will be covered as we step through the exercises but for more information take a look at

Building Running and Managing Containers in RHEL 8

What is a container registry?

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Setup

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Running Containers

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Red Hat Developer